DRAFT Total Maximum Daily Loads
For Lochloosa Lake (Nutrients)
AND
Cross Creek (Nutrients, Dissolved Oxygen, and Biological Oxygen Demand)
Alachua County, Florida

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1. Introduction

1.1 Purpose of Report

This report presents the efforts to develop Total Maximum Daily Loads (TMDLs) for Lochloosa Lake and Cross Creek. The Lake was verified as impaired by nutrients and Cross Creek was verified as impaired by nutrients and dissolved oxygen (DO). Both waters were included on the verified list of impaired waters for the Ocklawaha Basin that was adopted by Secretarial Order on August 26, 2002. Additionally, Cross Creek was on the 1998 303(d) list for biochemical oxygen demand (BOD) and was placed on the state's 2002 Planing List as potentially impaired for BOD. For this reason, the effects on BOD in Cross Creek of attaining standards for nutrients and DO will be discussed as a part of the report.

Section 303(d) of the federal Clean Water Act (CWA) requires States to submit lists of surface waters that do not meet applicable water quality standards (impaired waters). The methodologies used by the state for the determination of impairment are established in Chapter 62-303, Identification of Impaired Surface Waters (commonly referred to as the Impaired Waters Rule or IWR), Florida Administrative Code (FAC). Once a waterbody or waterbody segment has been verified as impaired and referenced in the Secretarial Order Adopting the Verified List of Impaired Waters, work on establishment of the Total Maximum Daily Load (TMDL) begins. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions (USEPA, 1991).

1.2 Identification of Water Body

Lochloosa Lake and Cross Creek are located in the eastern part of Alachua County, approximately 15 miles southeast of Gainesville, and four miles south of Hawthorne. Figure 1 shows the general location of the Lake and the contributing watershed. The lake has a surface of area of approximately 5,600 acres, a maximum depth of 11 feet, and a mean depth of 7 feet (Langeland, 1982). The total acreage of the Lake's watershed is 52,000 acres. A large drainage area to the north supplies most of the surface water inflow through Lochloosa Creek. The primary outflow is through Cross Creek, although an unknown amount of drainage occurs to Orange Lake through Lochloosa Slough in the southeastern corner of the Lake (Gottgens & Montague, 1987).

Cross Creek is the surface water connection between Lochloosa and Orange Lakes. The Creek is only about 1,600 meters (m) long and has a watershed of about 321 acres. The land uses are 143 acres of urban, 17 acres of agricultural uses, 53 acres of forested land, and about 108 acres of water and wetlands.

The lake has been described as a soft water, eutrophic lake with dense stands of aquatic macrophytes (Canfield, 1981). Based on data in the literature, lake color ranges from 45-157 PCU (Canfield, 1981). Based on data contained in the DEP database, the mean color is 115 PCU.

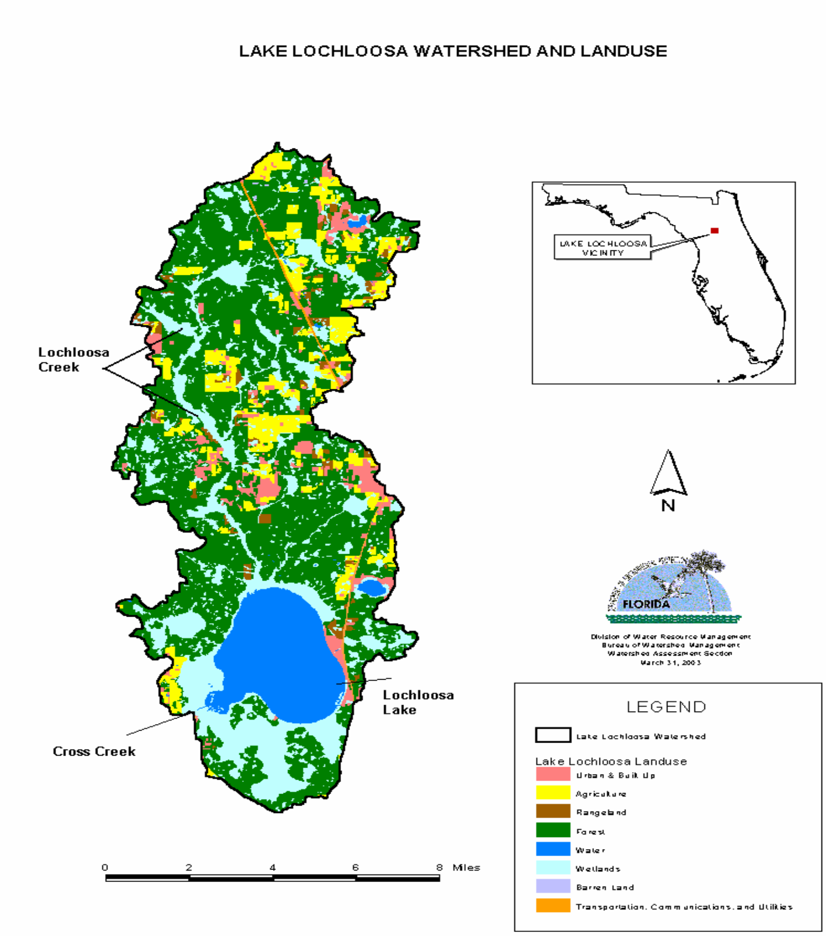
Lochloosa Lake, together with Orange and Newnans Lakes, are the main surface water bodies in the Orange Creek basin. The entire Orange Creek Basin covers about 1040 km^2 and is within the Central Lowlands topographical region (Clark et al. 1964). The area can generally be considered to having karst topography. In those portions of the basin overlain by the Hawthorne formation, the Floridan Aquifer is confined and therefore under artesian conditions. In these conditions, natural discharge from the Floridan Aquifer can occur where the confining layer is thin or absent. Such conditions exist at Magnesia Springs north of Lake Lochloosa (Pyne, 1985).

Poorly drained soil and the low elevation gradients of the area result in moderately high sheetflow and poorly defined channels. Ponds and wetlands occur throughout the area. The major sources of water to the lake include surface runoff, subsurface flow, and direct rainfall (Canfield 1981). Ground water from deep aquifers is not a regular part of the overall water balance of the Lake (Deevy, 1987). This is supported by data that indicate low mineral content of the Lake waters (Gottens & Montague, 1987).

The primary mechanisms by which water is lost from the Lake is drainage through the pervious sediments that make up the lake bottom, solution cavities, evapotranspiration, and discharge to surface streams, primarily Cross Creek. Losses of water from the lake by subsurface drainage may take on a higher degree of importance due to the high permeability of the lake bed (Deevy, 1987). As a point of comparison, of the 52 inches of annual rainfall within the watershed, it is estimated that only 5 inches leaves as surface drainage (Clark et al., 1964). While the lake responds quickly to monthly net rainfall, annual or decade long lake level variations appear to be controlled by changes in the artesian pressure affecting downward leakage through the lake bed (Deevy, 1987).

For assessment purposes, the watersheds within the Ocklawaha River Basin have been broken out into smaller watersheds, with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed. For the case of Lochloosa Lake and Cross Creek, the Lake and Creek have been assigned WBIDs 2738A and 2754, respectively.

Figure 1. Lochloosa Lake and Cross Creek watershed and land use



2. Statement of Problem

In accordance with IWR procedures, Lochloosa Lake was determined to be impaired for nutrients based on elevated TSI values for the lake. Based on available data, the long-term (1988 – 2001) average concentrations of total phosphorus (TP), total nitrogen (TN), and chlorophyll a (Chl a) were 0.062 mg/L, 2.18 mg/L, and 82.0 µg/L, respectively. The long-term average TSI calculated from these data according to the procedures adopted in the IWR is 76.9 (ranging from 54.8 to 89.5). For the verification period (January 1995 through December 2000), TP, TN, and Chl a concentrations averaged 0.066 mg/L, 2.77 mg/L, and 121.4 µg/L, respectively. The mean color of the lake was calculated as 115 platinum-cobalt units. The average TSI for the verified period was 80.4 (ranging from 62.3 to 89.5). It is important to note that the Lake would have been listed as verified impaired even if only one year (in the verified period) had a TSI of greater than 60. In the case of this Lake, TSI's calculated for each year of the verified period were greater than 60.

Cross Creek was determined to be impaired for nutrients based on elevated Chl a values and impaired for DO based on low (less than 5.0 mg/L) values. The impairment for DO was linked to nutrients and elevated BOD. Based on available data, the long-term average concentrations of BOD, DO, TP, TN, and Chl a were 3.6 mg/L, 5.2 mg/L, 0.072 mg/L, 1.86 mg/L, and 34.1 µg/L, respectively. It should be noted that Cross Creek was also listed on the 1998 303d list for Total Suspended Solids (TSS), but the Department has no water quality criterion for TSS. The Department proposed monitoring for turbidity (water quality criterion of less than or equal to 29 Nephelometric Turbidity Units (NTU) above natural background) as a means of determining the degree of impact from suspended particles. Based on data in the Department's database (54 monthly values collected between February 1994 and May 1998), the average turbidity is 5.9 NTU and the maximum value measured was 15.9 NTU. These data indicate full compliance with the turbidity criterion.

3. Description of Applicable Water Quality Standards and Criteria

Both Lochloosa Lake and Cross Creek are classified as Class III freshwaters, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Class III water quality criteria applicable to the observed impairment in the lake include the narrative nutrient criterion (nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna). For Cross Creek, the Class III water quality criteria applicable to the observed impairment include the narrative nutrient criterion and the DO criterion (5.0 mg/L). Cross Creek is also on the Department's Planning List as potentially impaired for the BOD criterion (shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case, shall it be great enough to produce nuisance conditions).

Because the nutrient criterion is narrative only, a nutrient related target was needed to represent levels at which imbalance in flora or fauna are expected to occur. For lakes, the IWR threshold for impairment is based on a trophic state index (TSI) and this TSI was used as the water quality target for the lake nutrient TMDL. Since the lake has a mean color greater than 40 platinum cobalt units, the IWR threshold for impairment is an annual mean TSI of 60, and the water quality target for the TMDL for the lake is therefore a TSI of less than 60. It is the Department's position that Cross Creek serves mainly as a conveyance system connecting Lake Lochloosa with Orange Lake and that the loadings to the Creek from Lochloosa Lake are the primary cause of the impairments to the Creek.

4. Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of nutrients in the Lochloosa Lake watershed and nutrients, DO, and BOD in the Cross Creek watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term point sources has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, runoff from agriculture, runoff from silviculture, runoff from mining, discharges from failing septic systems, and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under EPA's National Pollutant Discharge Elimination Program (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and from a wide variety of industries (see Appendix A for background information about the State and Federal Stormwater Programs).

For the purposes of allocating pollutant load reductions (see Section 6) required by a TMDL, the term "point source" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) AND stormwater systems requiring an NPDES stormwater permit. However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this section does not make any distinctions between the two.

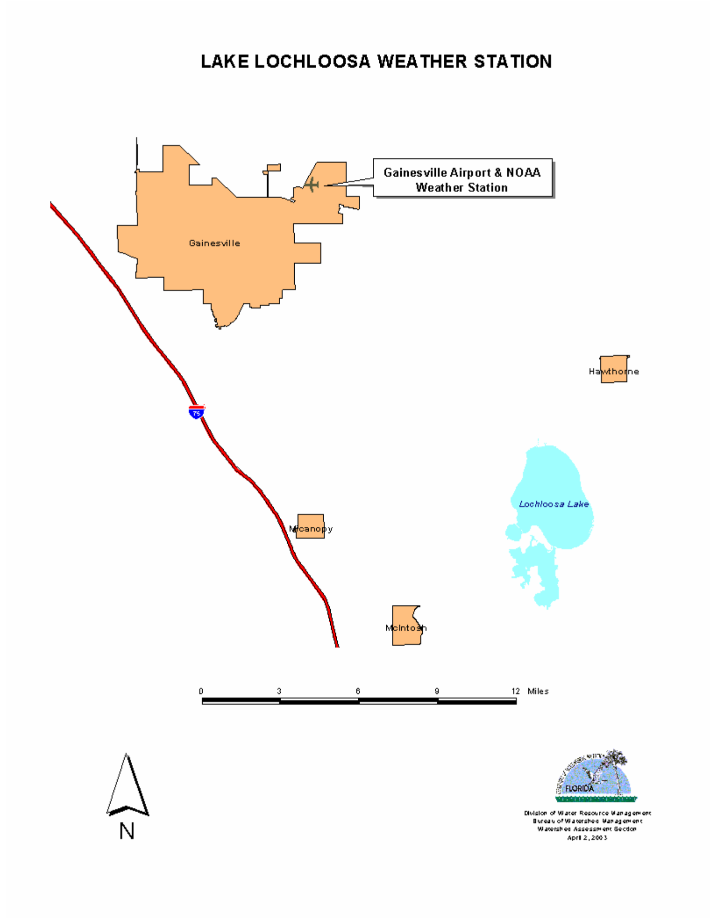
4.2 Land Use data

For this study, the Lochloosa Lake basin was divided into three subbasins: the Lochloosa Creek subbasin, the Hawthorne Creek subbasin (a dendritic system of streams northeast of Lochloosa Lake), and the Lochloosa Lake subbasin (the area that contributes to the lake through *direct* overland flow). Table 1 lists all the major land uses identified in each of the three subbasins. The total area in the Lochloosa Lake subbasin of 19,066 acres includes the surface of the lake, which varies year to year with water level. For annual average conditions, the lake surface area was assumed to be 5,649 acres, as reported by Florida LakeWatch (http://lakewatch.ifas.ufl.edu/). Predominant land covers in the Lochloosa Creek and Hawthorne Creek subbasins are forest and wetlands. Figure 1 presents the major landuses identified in the Lochloosa Lake basin.

4.3 Rainfall Data

With two major creeks discharging into the Lake and the surface-water connection through Cross Creek with Orange Lake to the South, Lochloosa Lake is classified as a *drainage* lake. This type of a lake is mostly supplied by surface runoff that originates from rainfall. The rainfall station with long-term records closest to the watershed is the Gainesville Airport and NOAA Weather Station (Figure 2). The monthly rainfall data were retrieved from the Climate Interactive Rapid Retrieval Users System (CIRRUS) database controlled by the Southeast Regional Climate Center at web site http://www.dnr.state.sc.us/pls/cirrus/cirrus.login. The annual average rainfall for 1988 – 2001 (14 years) was 47.2" for that station (see Table 2). The data reveal substantial variation in volume (23.8") during those fourteen years.

Figure 2. Location of weather station with respect to Lochloosa Lake basin



4.4 Watershed Management Model (WMM)

The Watershed Management Model (WMM) was developed by Camp, Dresser, & McKee for the Florida Department of Environmental Regulation in 1994 to evaluate nonpoint source pollution loads and control strategies from mixed-land-use watersheds. Pollutants simulated include nitrogen, phosphorus, lead, and zinc from point and nonpoint sources. The model includes a computational component for stream water quality analysis using simple transport and transformation formulations based on travel time. In this case, the loads are calculated as the product of effective rainfall and event mean concentrations (EMCs), which are specific to a land use.

<u>Septic Tanks</u>

To estimate the TN and TP loadings from leakage of septic tanks, WMM incorporates the concept of "septic tank failure loading rate." The annual failure rate reported for the country is 3 – 5 percent. Pollutant loading rates reported in the WMM Users Manual assume 50 gallons per capita per day usage. The mid-range of loading rates for failing septic tanks is 2.0 mg/L for TP (about a 160% to 250% increase) and for TN is 15.0 mg/L (about a 140% to 200% increase). To provide a Margin of Safety, this study adopted the high end of the range in the User Manual, which were 30.0 mg/L for TN and 4.0 mg/L for TP (WMM User Manual: 1998).

Another value required by WMM to estimate the influence from leaking septic tanks on TN and TP loading is the “septic tank failure rate”, which defines the frequency at which septic tanks may fail. Studies conducted on the water quality of the Ocklawaha River Basin found that annual frequency of septic tank repairs was about 0.97% (Basin Status Report 2001). For average annual conditions, it is conservative to assume that septic tank systems failures would be unnoticed or ignored for five years before repair or replacement occurred (WMM User Manual: 1998). Therefore, the septic tank failure rate used in this study was calculated by multiplying repairing frequency (0.97%) by 5 (years) and was about 5%.

The estimates of current annual average loadings from septic tanks to Lochloosa Lake are 69 lbs TP and 371 lbs of TN.

Table 1. Lake Basin Landuse and Acreages

			SUB-WATERSHED ACRES		
CODE	LANDUSE	LOCHLOOSA LAKE	UPPER LOCHLOOSA CREEK	LOWER LOCHLOOSA CREEK	HAWTHORNE
1000	Urban and Build-Up	61.08	99.38	9.32	105.85
	Low Density Residential	323.7	1082.19	364.44	388.25
	Medium Density Residential	89.79	0	0	168.24
	High Density Residential	0	0	0	18.72
2000	Agriculture	598.64	3905.5	421.85	512.89
3000	Rangeland	162.63	614	99.96	154.94
4000	Forest	6200.63	13626.65	4865.92	4091.36
5000	Water	5698.83	82.84	2.08	4.97
6000	Wetlands	5801.26	4176.97	1310.4	834.55
7000	Barren Land	0	21.65	0	0
8000	Transportation, Communication, and Utilities	128.92	202.94	0	41.21
TOTAL SUBWATERSHED ACRES:		19065.48	23812.12	7073.97	6320.98
NOTE: Acres were calculated using GIS.					

Table 2. Annual Average Rainfall recorded at Gainesville Municipal Airport gauge station.

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Inches	55.8	40.5	42.3	51	54.3	43.7	48.9	51.2	54.7	58.2	45.6	38.3	34.4	42.1

Model calibration

The area of the two tributary (stream drained) subbasins (Lochloosa Creek and Hawthorne Creek) is more than twice the area of the Lochloosa Lake subbasin. These two tributary basins drain to the Lake through several streams (Figure 3). Because the flow in those streams has no known hydrologic records at the points where they discharge to the Lake, the WMM was used to simulate the annual-average flow of these streams and the nutrient loads delivered to the Lake from the land north of the Lake. The third subbasin (area directly connected to the Lake) was modeled by EUTROMOD, for which the outcomes of the previous two simulations of WMM became a point-source input.

WMM stores several lists of default parameters that are usually not known for a particular basin. One of these parameters is "percentage of impervious area" quantified by landuse. Harper's (1994) category "percent impervious" apparently provides the values corresponding to the hydrologic (and intuitively understood) term "impervious." However, WMM actually uses "percent of impervious directly connected to the water." The reason for this differentiation is that overland flow originating from impervious area most often discharges into a pervious soil before reaching a water body, and is subject to infiltration. For this reason, the default WMM values for "percent impervious" were used as the starting values for the modeling. Some modifications, however, were necessary and the final values used are shown in Table 3.

Figure 3. Lochloosa Lake basin split into three subbasins colored in green (Lochloosa Creek), brown (Hawthorne Creek), and orange (Lochloosa Lake). Lochloosa Creek subbasin has been further divided into Upper and Lower subbasins (dark and light green).

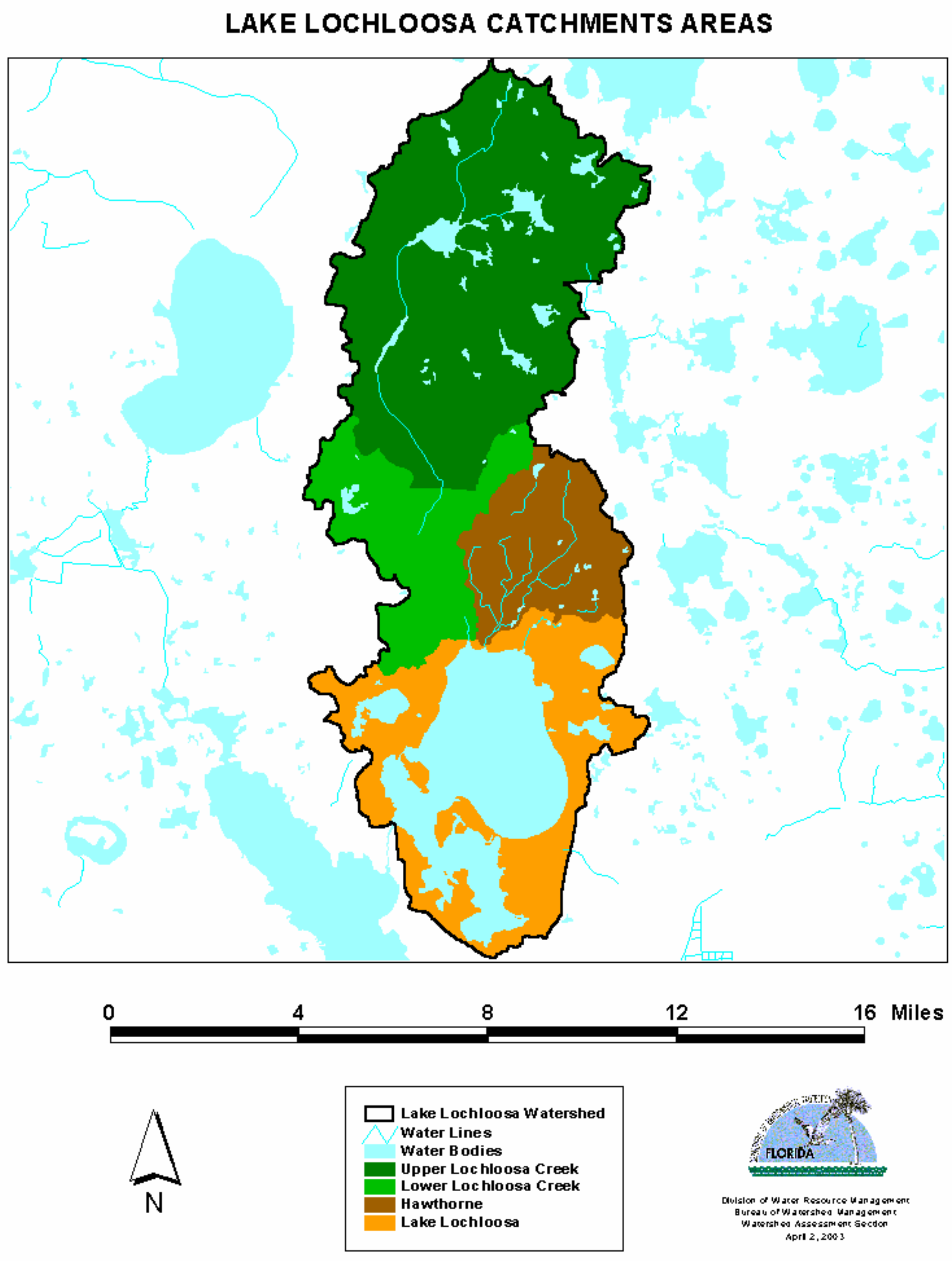


Table 3. Percent impervious by land uses in Lochloosa Creek and Hawthorne Creek subbasins.

Land use type	% impervious	Reference
Forest	0.5	A
Urban open	0.5	A
Agricultural	3.7	B
Low density residential	12.4	B
Medium density residential	18.7	B
High density residential	29.6	B
Highways	36.2	B
Water	30	C
Rangeland	3.7	D
Wetlands	30	C

A = WMM model manual
B = Mark T. Brown, in ‘South Dade Watershed Project’, 1995, University of Miami/SWFWMD
C = Mike Heyl, CDM, personal communication
D = Harvey H. Harper, and Eric H. Livingston , in ‘Everything You Always Wanted to Know About Stormwater Management Practices But Were Afraid to Ask’, 1999, Biennial Stormwater Research Conference, Tampa, Florida.

The land uses in the three subbasins of Lochloosa Lake were placed in one of the following categories (see also Table 1): Urban, Low density residential, Medium density residential, High density residential, Agriculture, Rangeland, Forest, Water, Wetlands, and Transportation, Communications, and Utilities (Roads).

For the modeling, the level 1 land use categories commercial and industrial were aggregated into the category ‘Urban’. In this study, ‘Transportation’ primarily means Roads. An additional land use of 21.7 acres of ‘Barren Land’ (identified in only one of three subbasins) was re-categorized as ‘Urban’ because of the lack of default values for barren land. Similarly, due to the unavailability of ‘percent impervious’ for the Rangeland category, it was assigned the same value as for Agriculture on Harper’s list (3.7%).

Water and wetlands are typically assigned 100% impervious. Department experience with using WMM suggests that this value is over-estimated. In previous projects, use of 30% fit well to measured annual discharges (Mr. Mike Heyl, personal communication). Mr. Heyl selected that value based on the work of K. Heinburg in 'Hydrology of North-Central Florida Cypress Domes.'

Major roads have an estimated percent impervious of 90%. However, water-conveying swales accompany most of the roads, and runoff abundantly infiltrates there. Data from Mark Brown measured at Gainesville, Ft. Myers, and Tampa generated a value of 36.19% imperviousness for major roads, and this value was used for the calculations.

Because no communications and utilities landuses were identified in the GIS analysis of the basin, the category “Transportation, Communications, and Utilities” should be read as ‘Roads.”

Event mean concentration (EMC) values were selected from Harper's table for Central and South Florida. The original table provided (among others) concentrations of total nitrogen (TN). However, for the simulation by the WMM model, TN had to be split into total Kjeldahl nitrogen (TKN) and nitrite + nitrate (NO23). EMC values for nitrogen species were estimated based on proportions for average concentrations of TKN and NO23 for the nation and provided in the manual for WMM model. The sum of TKN and NO23 is equal to the TN estimate provided by Harper.

An EMC for forest landuse was not available on Harper's list, and an estimate provided by Mike Heyl was used. Data for urban open followed the national average EMCs provided in the manual for WMM. The set of EMCs used in simulations of nutrient loads to both creeks is shown in Table 4.

Table 4. Event Mean Concentrations (EMCs) by Land Use.

Land use type	Event Mean Concentration (mg/L)				Reference
	TP	TKN	NO23	TSS	
Forest	0.050	0.94	0.31	11.0	C
Urban open	0.230	1.36	0.73	216.0	A
Agricultural	0.476	1.84	0.64	94.3	D
Low density residential	0.177	1.20	0.57	19.1	D
Medium density residential	0.300	1.56	0.73	27.0	D
High density residential	0.490	1.47	0.95	71.7	D
Highways	0.340	1.70	0.38	50.3	D
Water	0.110	1.10	0.20	3.1	D
Rangeland	0.476	1.84	0.64	94.3	D
Wetlands	0.190	1.17	0.43	10.2	D

The WMM also requires runoff coefficients for pervious and impervious area. Intuitively, it is understood that impervious area does not infiltrate water. Ideally, the runoff coefficient should be 1. Allowing for some small surface detention, the value 0.95, which is often quoted in the literature, was used in this study. The runoff coefficient for pervious area was estimated in the process of calibration. The Lochloosa Creek subbasin was divided into Upper and Lower subbasins. Four years of daily flows (January 99 – December 2002) from the USGS gauging station at the border between the Upper and Lower subbasins were available for model calibration. Care was taken to ensure that the total runoff and rainfall correspond to the same 12-month periods. The total runoffs calculated from the USGS flow data and the corresponding rainfalls, recorded at the Gainesville Municipal Airport Weather Station, are shown in Table 5.

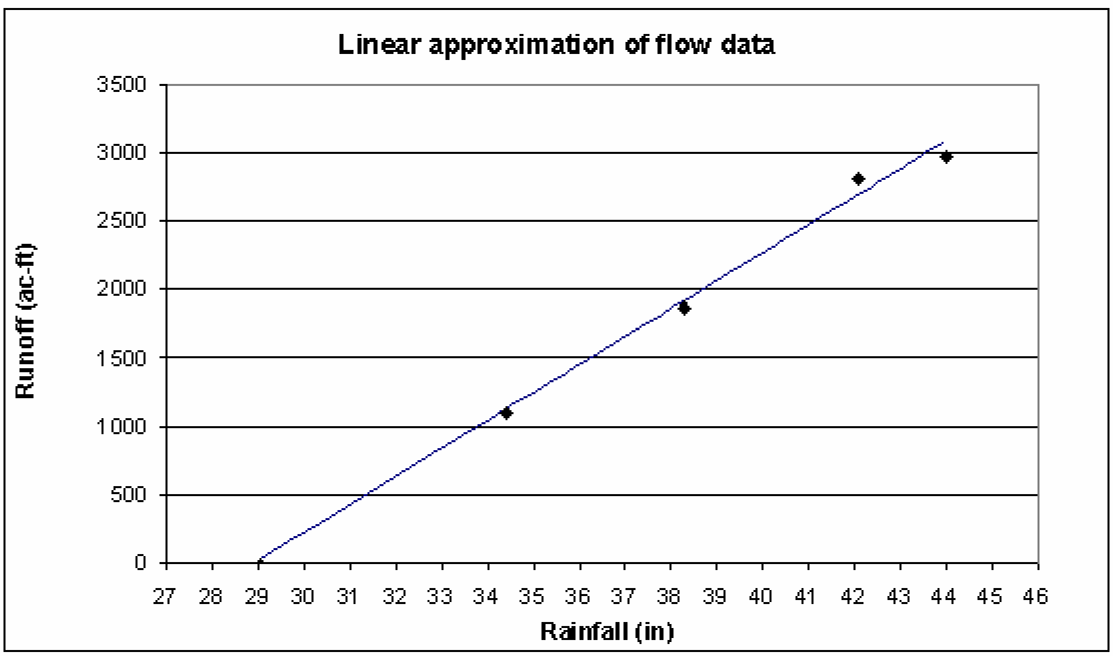
Table 5. Annual rainfall and runoff (measured vs simulated) for model calibration

12-month period	Rainfall (inches)	Measured runoff (ac-ft)	Simulated Runoff (ac-ft)	Percent Difference[1]
1999	38.3	1865	1884	1
2000	34.4	1101	1094	1
2001	42.1	2810	2654	6
2002	44.0	2975	3042	2

[1]The percent difference was calculated as Percent Difference (%) = 100 x | Model – Data | / Data.

Water losses within the basin may vary annually depending on antecedent-years precipitation and evapotranspiration, which controls the content of moisture in the soil. A plot of annual rainfalls and the corresponding creek discharges formed almost a straight line as shown on Figure 4. The least-square method provided an intercept at 29" of rainfall. This provides an estimate of the annual-average, volume of rainfall retained in the basin.

Figure 4. Rainfall and runoff data from Upper Lochloosa Creek basin and linear approximation of effective rainfall



This estimated value for initial retained water (29 inches) was subtracted from annual rainfall before running the WMM model. This reduction in rainfall was needed because the model does not provide any estimate of rainfall retained in the depressions of a basin, which seem to be appreciable around Lochloosa Creek and because the runoff coefficients would have had to be reduced to unrealistically low values to match the measured discharges.

The structure of WMM does not allow full optimization of both impervious and pervious runoff coefficients. The runoff calculation is of the form:

(1) $$\frac{Q}{P\,A} = (1 - IMP)\,C_p + (IMP)\,C_I$$

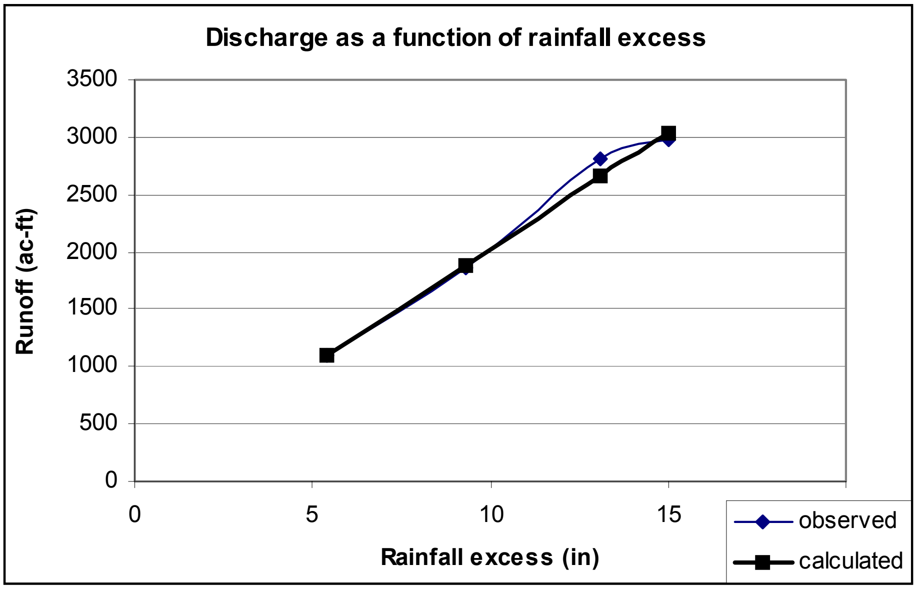
Where:

A	=	area of a land use,
C_p and C_i	=	pervious and impervious runoff coefficients,
Q	=	discharge,
P	=	annual precipitation,
and		
IMP	=	a ratio of impervious area

From this equation, it is seen that the coefficients, C_p and C_i, are independent of the hydrological data and do not change with years (mathematically speaking, for two years, two equations like the above are linearly dependent). Therefore, no matter how many hydrologic events would be analyzed, there is always one algebraic equation with two unknowns. For this reason, the value of C_i had to be arbitrary selected. Mathematically, there are infinite numbers of pairs (C_p, C_i) that provide the same total runoff. Unfortunately, the corresponding loads of pollutants are not always the same. Therefore, some local estimate of either C_p or C_i is recommended before calculating loads using WMM.

Figure 5 shows the observed and simulated discharges as a function of excess rainfall numerical values of the simulated discharges are provided in the last column of Table 5). By 'excess' it is meant 'above the volume retained in surface depressions.' The simulated discharges were obtained with C_i = 0.95 and C_p = 0.036. It is noteworthy that this is a very low value for a pervious runoff coefficient, particularly given the subtraction of estimated rainfall losses in surface depressions.

Figure 5. Measured and simulated discharges with relation to rainfall reduced by surface retention



Nutrient loads into Lochloosa Creek and Hawthorne Creek estimated by Watershed Management Model (WMM)

To estimate total nutrient loads to the lake, it was assumed that the runoff parameters estimated for Upper Lochloosa Creek are representative of the remaining subbasins. The WMM was then run with 47.2 – 29 = 18.2 inches of rain for the Lochloosa Creek and Hawthorne subbasins. Annual average rainfall was estimated from the records of the Gainesville weather station, approximately 15 miles north-west of the subbasins. From the four years of flow data in Lochloosa Creek, it was observed that there was no flow during dry periods. Therefore, baseflow for this period was assumed zero for those creeks.

The GIS analysis of the terrain and review of available literature revealed several springs in both subbasins, with no known monitoring records. As the load from these springs is unknown, they were not included in the analysis. Table 6 summarizes the total estimated annual discharge and nutrient loads from both creeks to the Lake. It was assumed that all of the loads eventually reach the Lake.

Table 6. Discharge and loads from tributary sub basins simulated by WMM model.

Subbasin	Drainage area	Storm water	TN	TP
	(Acres)	(acre-feet/year)	(lbs/year)	(lbs/year)
Lochloosa Creek	30,886	4,742	20938	2440
Hawthorne Creek	6,321	870	3997	449

5.0 Determination of Assimilative Capacity

5.1 EUTROMOD Watershed and Lake Modeling Software

EUTROMOD is a spreadsheet-based modeling procedure for eutrophication management developed at Duke University and distributed by the North American Lake Management Society. The steady-state modeling system allows for calculation of nonpoint source loading, evaluation of the contribution of point source (either wastewater treatment plant or inflowing stream) to the total loading, and then simulation of the lake's response. The nonpoint source loading calculation follows the Universal Soil Loss Equation, with the required parameters for each landuse provided by the user. Both the nutrients attached to the soil and those dissolved in the overland flow are part of the total loads reaching the lake. The model results include the most likely predicted phosphorus and nitrogen loadings for the whole watershed and separately for each landuse category.

<u>Setting the Parameters and Model Estimation</u>

The main outflow of the Lake is through Cross Creek to Orange Lake. As was the case with the previously analyzed subbasins, the Lochloosa Lake subbasin has limited data external to the Lake. However, the simulation of nutrient loads by EUTROMOD was compared to the loads calculated from the measured concentrations.

The values for Event Mean Concentrations were the same as those applied to the two other subbasins (Table 4). One advantage of EUTROMOD is that it can use separate runoff coefficients for each type of landuse. Additionally, EUTROMOD uses total rainfall slightly different than WMM. The Lochloosa Lake subbasin has no channelized flow into the Lake, and data on the overland discharge to the Lake could not be found. The runoff coefficients were assigned values based on Harper's reports.

Model input values for the percent of nutrients bound and retained in soil were based on EPA recommendations, as described in 'Water Quality Assessment,' 1985, Section 3.4.4.1. For all landuses, the values used were 176 mg TP/ kg of eroded soil and 1000 mg TN/kg of eroded soil.

According to the topographical map, the slope of the subbasin's surface was found to vary between 100 ft and 50 ft along five randomly selected transects. The average difference, 20 ft change in elevation over approximately one half of a mile, corresponds to a slope of 0.43°. This slope was then used as the estimate of the length-slope factor (0.21) used by the Universal Soil Loss Equation.

Estimation of Lake Discharge

The *ungaged* discharge from Lake Lochloosa was estimated from a water balance equation with no consideration to subsurface flow or ground water interaction. The WMM was run for the area directly connected to the Lake in a similar way to the Lochloosa Creek and Hawthorne subbasins. The simulation provided 10,938 ac-ft of runoff. Together with 5,612 ac-ft from both creeks, this provides 16,550 ac-ft of runoff, into the Lake. Converting the ac-ft of runoff into inches in the Lake generates the equivalent of 35.14 inches covering the Lake's surface. Annually, an average of 47.19 inches of rainfall directly falls on the lake, giving a total of 82.33 inches of water entering the lake (this number together with the lake surface area would be equal to the volume of water entering the Lake). From this, an annual lake evaporation of 51 inches (taken from "Hydrology of Central Florida Lakes – a Primer", by Donna Schiffer, USGS Circular 1137, 1998) was subtracted. The remaining 31.33 inches of rainfall was uniformly spread over the watershed's area, providing 13.1 inches of runoff from the basin (0.33 meters). This estimate was used in EUTROMOD as the estimate of annual discharge from Lake Lochloosa. For a better understanding of the water and mass balance for the Lake, the installation of a gaging and monitoring station at the outlet of the Lake is strongly recommended.

Some portion of the sediment carried by overland flow towards the lake is likely to be trapped in depressions and by natural sedimentation. The likelihood of being trapped increases with the length of the path. From a plot of the delivery ratio as a function of distance, provided with the documentation of EUTROMOD, the delivery ratio for 400 meters (an average path of overland flow in this basin) was 0.344. The corresponding trapping efficiency of 0.656 (one minus the delivery ratio) was assigned to the Lochloosa Lake drainage subbasin.

The LakeWatch website maintained by the Institute of Food & Agricultural Sciences at the University of Florida provided a bathymetric map of the Lake. On average, the central part of the lake is 7 ft deep, then slopes gently up to 5 ft, and afterwards the depth is reduced more rapidly towards the shore. According to LakeWatch, the average depth of the lake is 4.6 feet (1.4 m).

Annual average concentrations of TN, TP, and chlorophyll a for the lake were calculated for 1994-2000 from the available data and are shown in Table 7. Table 7 also includes lake elevation, but water surface elevations were available only for 1996 – 2000. Given the importance of lake elevation data, years without lake elevation data (1994 and 1995) were eliminated from further analysis.

Characteristic curves for Lake Lochloosa were used to determine the capacity and surface area of the Lake as a function of water elevation. These curves were available in Robison, C. P., G. B. Hall, C. Ware, and R. B. Hupalo. 1997. "Water Management Alternatives: Effect on Lake Levels and Wetlands in the Orange Creek Basin." St. Johns River Water Management District. Special Publication SJ97-SP8 (Appendixes). From those curves, the water surface and the depth of the Lake were estimated and used in EUTROMOD simulations for 1996 through 2000 for annual average conditions.

Table 7. Annual Average Measured and EUTROMOD Simulated TN, TP, Chl a, Lake volume, Elevation, and Rainfall (1994 – 2000).

Year	Precip. (in)	TP Measured (µg/L)	TP predicted (µg/L)	TN Measured (µg/L)	TN Predicted (µg/L)	CHL a measured (µg/L)	CHL a Predicted (µg/L)	Elev. (ft)	Volume (ac-ft)
1994	48.9	49.83		2,012.79		74.91			
1995	51.2	44.34		1,420.86		36.63			
1996	54.7	45.83	42.0	1,775.61	1,785.0	73.46	19.9	58.29	61,630
1997	58.2	52.26	47.6	1,975.71	1,940.3	75.06	22.5	57.68	55,090
1998	45.6	60.04	33.8	1,924.53	1,422.1	112.33	15.1	58.80	65,480
1999	38.3	67.59	38.1	2,683.44	1,253.1	168.32	13.8	56.96	48,750
2000	34.4	87.39	42.6	5,149.77	1,133.5	246.80	13.0	54.99	36,070

Table 8. Measured and EUTROMOD Predicted TN, TP, and Chl a with Percent Error.

Year	TP Percent Error	TN Percent Error	Chl a Percent Error
1996	8.4	0.5	73.5
1997	8.9	1.8	70.0
1998	43.7	26.1	86.6
1999	43.6	53.3	91.8
2000	51.2	77.9	94.7

EUTROMOD Results

As shown in Tables 7 and 8, EUTROMOD model results were generally poor. The concentrations predicted in the Lake by EUTROMOD were much lower than the measured concentrations. Predications for TN and TP were fairly good in wetter than average years, but become progressively worse for years with less than average rainfall. Predicted concentrations of nitrogen on average were more than fourfold lower than the measured data, and predicted chlorophyll a concentrations were up to nineteen times lower than the measurements. Additionally, the measured data show increasing concentrations for TP, TN, and Chl a over time, while the results from the EUTROMOD modeling showed decreasing trends. The measured rainfall and estimated Lake volumes also showed a decreasing trend over this time period.

Additionally, measured concentrations for 1999 and 2000 indicate that TN load in the lake increased by 67,760 kg, while at the same time the mass of TP declined by 176 kg. This is one of several changes taking place in Lochloosa Lake in recent times whose nature is not yet well understood. It may be that errors in measured data, such as lake stage, concentrations, flows, etc., might combine to ‘create’ a phenomena not easily explained by hydrology and mathematics. For example, the Lake’s area in June 1996, which was estimated from the records of water elevation and transformed by the characteristic curve developed by SJRWMD, was approximately 9,100 ac. For the same period, the Florida LakeWatch website (http://lakewatch.ifas.ufl.edu/) provided an estimate of only 4,350 ac.

In EUTROMOD, the predicted in-lake concentrations are substantially affected by the residence time in the lake. The estimated outflow from the Lake of 0.187 m^3/y comprises only 13% of the average lake volume. However, the total mass of TP and TN in Lochloosa Lake, calculated as the product of the simulated concentrations and lake volumes, did not support the mass accumulation calculated from the measured concentrations. Moreover, changes of the simulated masses over time had neither a visible trend consistent with the variation of the Lake's volume, nor with the measured annual precipitation. The Department did not consider that EUTROMOD was sufficiently reproducing the observed data and trends to be used to develop a nutrient TMDL for the Lake.

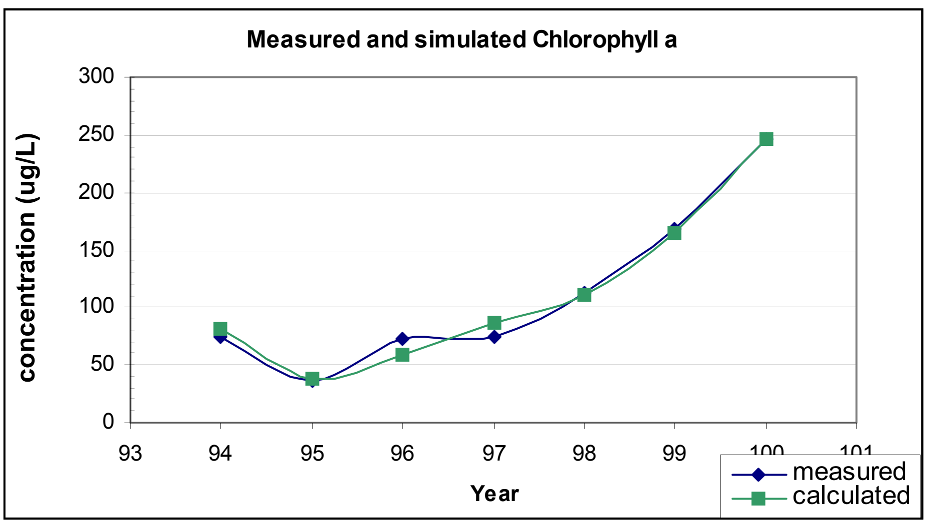
5.2 Chl a Regression Model

Searching further for a statistical relationship between nutrients and Chl a concentrations that better represented the algal biomass than the results from EUTROMOD, it was found that the measured concentrations of TP and TN from Table 7 correlate well with the Chl a concentrations. The match of Chl a concentrations predicted by the regression equation to the measured annual-average data are shown on Figure 6.

The regression equation is:

Chl a (µg/L) = -166.863 + 3222.7 * TP + 45.6657 * TN – 0.5979 * EXP(TN)

Figure 6. Measured vs Estimated Concentrations of chl a obtained from regression analysis.



The calculated concentrations differ most from measured concentrations for 1996. The probable cause of this is that there was an incomplete record of water levels for the preceding year 1995. The only available water levels in the Lake for 1995 were for the last period, October – December, and they served as data representative for the whole year.

Based on the results presented in Figure 6, the Department believes the Chl a regression equation can be used with the loading model results to predict how changes in loadings to the Lake will affect Lake water quality.

5.3 Calculation of TSI

The TN, TP, and Chl a predicted by the regression equations using the average Lake volume and rainfall (1996-2001) resulted in a TSI of 83.1. Based on the average of the measured data for the same period, a TSI of 80.2 was calculated.

TSI was calculated using the equations referenced in the IWR, which are:

$$\mathbf{TSI = (CHLA_{TSI} + NUTR_{TSI})/2}$$

Where:

$$\mathbf{CHLA_{TSI} = 16.8 + 14.4 * Ln\ (Chla)}$$
$$\mathbf{TN_{TSI} = 56 + 19.8 * Ln\ (TN)}$$
$$\mathbf{TN2_{TSI} = 10 * [\ 5.96 + 2.15 * Ln\ (TN + 0.0001)]}$$
$$\mathbf{TP_{TSI} = 18.6 * Ln\ (1000 * TP) - 18.4}$$
$$\mathbf{TP2_{TSI} = 10 * [\ 2.36 * Ln\ (1000 * TP) - 2.38],\ and}$$

$$\mathbf{NUTR_{TSI} = TN2_{TSI}\ if\ (TN/TP) < 10}$$
$$\mathbf{NUTR_{TSI} = TP2_{TSI}\ if\ (TN/TP) > 30}$$
$$\mathbf{NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2]\ if\ (TN/TP)\ is\ between\ 11\ and\ 30}$$

Where

Chl a = chlorophyll a in µg/L,
TN = total nitrogen in mg/L,
TP = total phosphorus in mg/L, and
Ln designates natural logarithm.

5.4 Seasonal/Annual Data Analysis

The seasonal variations of TP, TN, and Chl a in Lochloosa Lake for 1988 -2000 are provided in Tables 9, 10, and 11. The seasonal-average concentrations show high variability over the period of record, and this is summarized in the last row of each table (values in bold correspond to the verified period).

Table 9. Seasonal/Annual Average Chl a Concentrations (1988-2001).

CHLOROPHYLL A (µg/L)					
Year	Spring	Summer	Fall	Winter	Annual Average
1988	20.8	18.5	6.2	12.0	14.4
1989	17.8	13.6	12.0	8.1	12.9
1990	1.6	32.1	21.6	9.6	16.2
1991	175.9	44.1	32.1	29.5	70.4
1992	16.0	*	14.4	12.0	**
1993	13.6	29.5	89.5	9.6	35.6
1994	49.5	69.0	74.5	71.5	66.1
1995	**18.6**	**22.7**	**27.0**	**56.5**	**31.2**
1996	**54.5**	**116.0**	**75.0**	**30.5**	**69.0**
1997	**39.0**	**20.0**	**128.0**	**79.5**	**66.6**
1998	**75.5**	**154.5**	**153.5**	**79.0**	**115.6**
1999	**269.2**	**53.7**	**241.0**	**143.5**	**176.9**
2000	**293.5**	**226.0**	**190.0**	**232.5**	**235.5**
2001	**182.2**	**190.5**	**145.7**	**102.5**	**155.2**
overall average	87.7	76.2	86.5	62.6	82.0
verified period	**133.2**	**111.9**	**137.2**	**103.4**	**121.4**

* Insufficient data to calculate quarterly average.
** No annual average due to missing one quarterly average.

Tables 9, 10, and 11 also show the average concentrations for each season over the period of record for all three water quality components. Chl a values were high in all four seasons (Figure 7), but chlorophyll levels drop a little during the winter season. This is to be expected due to the lower light and temperature in winter, and due to the lower winter rainfall, which reduces phosphorus loading to the Lake.

Table 10. Seasonal/Annual Average TP Concentrations (1988 – 2001).

TOTAL PHOSPHORUS(µg/L)					
Year	Spring	Summer	Fall	Winter	Annual Average
1988	66.6	63.5	71.3	43.4	61.2
1989	55.8	49.6	41.8	46.5	48.4
1990	43.4	43.4	54.2	52.7	48.4
1991	60.4	52.7	74.4	82.1	67.4
1992	97.6	37.2	62.0	51.1	62.0
1993	72.8	48.0	62.5	62.0	61.3

1994	44.0	50.5	45.5	71.5	52.9
1995	**50.0**	**39.0**	**36.5**	**66.0**	**47.9**
1996	**49.2**	**53.0**	**47.0**	**43.0**	**48.1**
1997	**47.0**	**34.0**	**73.5**	**60.5**	**53.8**
1998	**57.0**	**63.5**	**57.0**	**65.5**	**60.8**
1999	**81.0**	**58.0**	**73.0**	**63.5**	**68.9**
2000	**109.5**	**93.0**	**88.0**	**89.0**	**94.9**
2001	**107.5**	**65.0**	**61.0**	**111.5**	**86.3**
overall average	67.3	53.6	60.6	64.9	61.6
verified period	**71.6**	**57.9**	**62.3**	**71.3**	**65.8**

TSI values were calculated for each season for the period of record (1988 – 2001) and averaged for each season. The average seasonal TSIs, shown on Figure 8, are quite stable between the seasons, ranging between 67.5 – 71. For the long-term average annual conditions, the TSI was 82.0 with a wide range of variation (54.8 – 89.5). As explained in Section 2, these TSI values classify Lochloosa Lake as an impaired water. The long-term TSI was calculated with the exclusion of data from 1992, which had insufficient data to calculate an annual TSI. Based on these results it was concluded that seasonal differences were not significant enough to warrant a TMDL other than that based on annual average conditions.

The seasonally-averaged rainfall pattern, recorded at the Gainesville Airport and NOAA Weather Station during the period 1988 – 2001, is shown on Figure 9. Comparing it with the results in Table 10 it can be seen that the phosphorus concentration does not follow the rainfall pattern. In particular, during the winter season with minimum rainfall, the corresponding TP concentration is quite stable. This implies that surface water runoff may not be the only significant source of this chemical constituent. Ground water could play a larger role in the Lake's hydrology than anticipated. The soil of Central Florida is rich in phosphorus, which is dissolved in the ground water. Central Florida lakes often exhibit a 'flow-through' condition in which ground water flowing into the lake along one shoreline flows out of the lake along the opposite shoreline. The possible interaction of Lochloosa Lake with ground water was not analyzed in this report due to lack of data.

Table 11. Seasonal/Annual Average TN concentrations (1988 – 2001)

TOTAL NITROGEN (mg/L)					
Year	Spring	Summer	Fall	Winter	Annual Average
1988	1.40	0.50	1.20	1.10	1.05
1989	1.30	1.10	1.10	1.00	1.13
1990	0.90	0.20	1.70	1.00	0.95
1991	3.00	1.80	1.50	1.70	2.00
1992	1.60	*	1.60	2.00	**
1993	1.40	1.80	2.60	1.40	1.80
1994	1.70	2.20	2.00	2.10	2.00
1995	**1.30**	**1.00**	**1.10**	**2.20**	**1.40**
1996	**1.90**	**2.00**	**2.20**	**1.10**	**1.80**
1997	**1.20**	**1.00**	**2.50**	**2.10**	**1.70**

1998	**1.70**	**2.20**	**2.40**	**1.60**	**1.98**
1999	**3.50**	**1.40**	**3.70**	**2.50**	**2.78**
2000	**6.10**	**5.50**	**4.70**	**5.00**	**5.33**
2001	**6.20**	**3.80**	**4.00**	**3.70**	**4.43**
overall average	2.37	1.88	2.31	2.04	2.18
verified period	**3.13**	**2.41**	**2.94**	**2.60**	**2.77**

* Insufficient data to calculate quarterly average.
** No annual average due to missing one quarterly average.

Figure 7. Seasonal Average Chl a (µg/L), TN (mg/L), and TP (µg/L) (1988 – 2001)

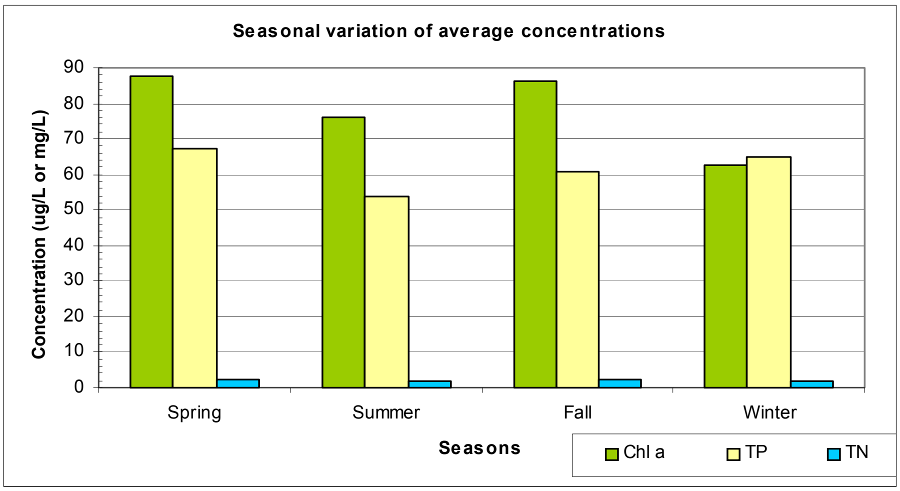


Figure 8. Seasonal Average TSI (1988 – 2001)

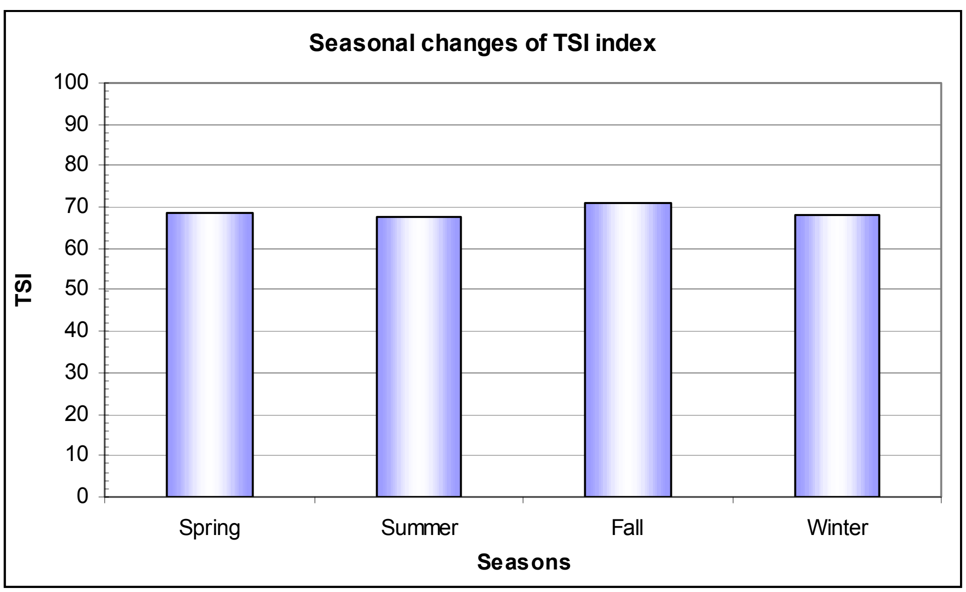
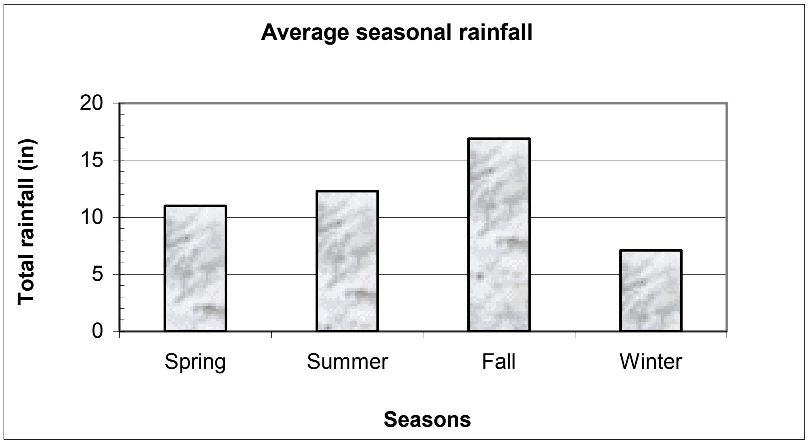


Figure 9. Seasonal Average Rainfall recorded by Gainesville Airport & NOAA Weather Station (1988 – 2001)



The measured concentrations of nutrients were also analyzed for possible temporal trends. In Figure 10, the measured concentrations were divided by the average concentration for the period of record (for chlorophyll 82.0 µg/L, for total phosphorus 0.062 mg/L, and for total nitrogen 2.18 mg/L) to depict the relative concentrations of each parameter. The graph of annual-average concentrations for all three chemical constituents showed an increase of concentrations over time (Figure 10). The continuous increase above the long-term average is noticed after 1997 for all three chemical constituents. The concentrations reached the peak in 2000, the year in which recorded rainfall was least over the period. Figure 11 shows the distribution of relative rainfall in that period.

Figure 10. Annual Average relative concentration TN, TP, and Chl a (1988 – 2001)

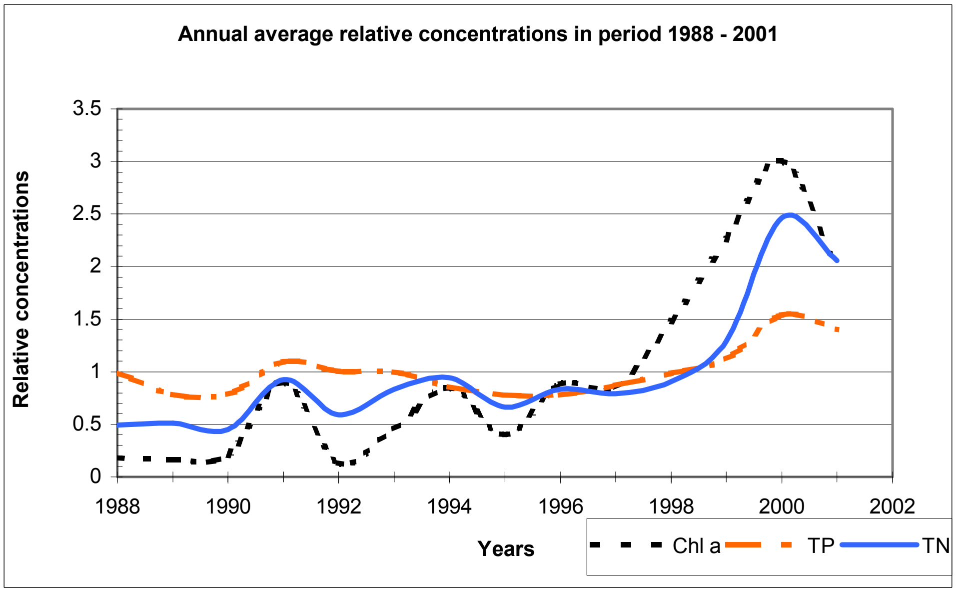
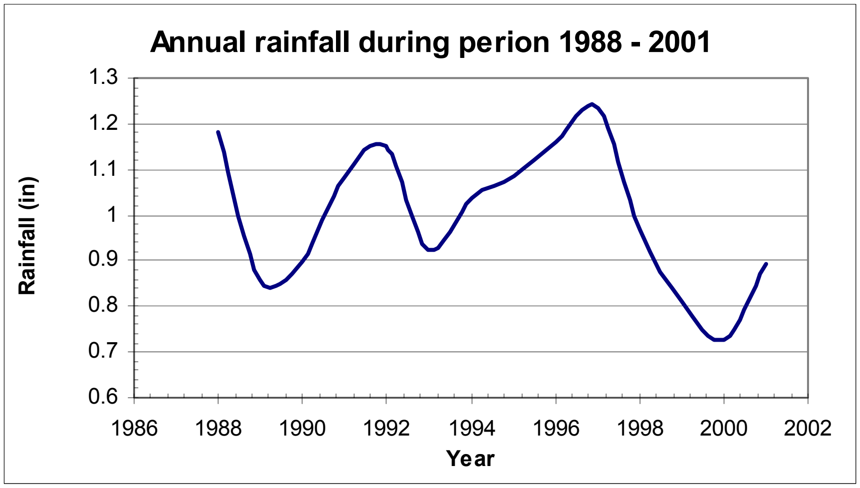


Figure 11. Annual Average Relative Rainfall (1988 – 2001)

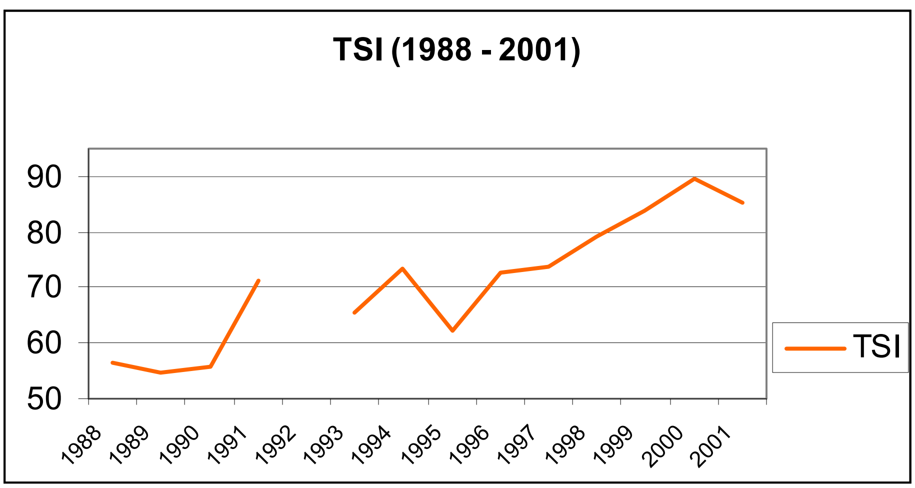


It is tempting to link the increasing concentrations, shown in Figure10, with the decreasing rainfall. The increase of concentrations after 1997 might be explained by the expected reduced water volume in the Lake. However, the estimates of water volume based on recorded water stages did not support this hypothesis, and the cause of the increase of concentrations of nutrients after 1997 remains unclear.

5.5 Historical Trend in TSI

The annual-average TSI, excluding 1992, is 76.9. Since 1998, the TSI has continuously remained above the average. Considering that a TSI greater than 60 is used as the threshold for impairment, Figure 12 indicates that Lochloosa Lake has been continuously impaired since 1991, and the problem is steadily increasing.

Figure 12. Annual Average TSI (1988 – 2001)



The annual average concentrations for TN, TP, and Chl a, TSI, rainfall, and percent of lake surface area covered by macrophytes for the overall and verified period are summarized in Table 12 and depicted on Figure 13. In order for the y-axis scale to display all variables on the same graph, the TN concentrations from Table 10 were multiplied by 10 and TP concentrations are shown on the graph as µg/L. It is clear that conditions in the lake oscillated up and down from 1988 through 1997. Beginning in 1997, there has been a dramatic increase in TN, TP and Chl a in the Lake. However, the relative increase varies with each parameter.

Table 12. Lochloosa Lake Annual Average
TN, TP, Chl a, TSI, Percent Macrophyte Coverage, and Rainfall

Year	TN (mg/L)	TP (mg/L)	Chl a (µg/L)	TSI	Percent Macrophyte Coverage	Rainfall (Inches)
1975					6.2	
1976					0.7	
1977					2.7	
1978					20.4	
1979					50.7	
1980					53.1	
1981					58.9	
1982					68.2	
1983					37.2	
1984					14.0	
1985					79.9	
1986					14.5	
1987					5.3	
1988	1.05	0.061	14.4	56.4	85.4	55.8
1989	1.13	0.048	12.9	54.8	93.4	40.5
1990	0.95	0.048	16.2	55.6	56.5	42.3
1991	2.00	0.067	70.4	71.4	11.3	51.0
1992		0.062			88.6	54.3
1993	1.80	0.061	35.6	65.5	15.8	43.7
1994	2.00	0.053	66.1	73.5	0.1	48.9
1995	**1.40**	**0.049**	**31.2**	**62.3**	**5.1**	**51.2**
1996	**1.80**	**0.048**	**69.0**	**72.6**	**4.6**	**54.7**
1997	**1.70**	**0.054**	**66.6**	**73.8**	**7.1**	**58.2**
1998	**1.98**	**0.061**	**115.6**	**79.2**	**0.7**	**45.6**
1999	**2.78**	**0.069**	**176.9**	**83.7**	**0.0**	**38.3**
2000	**5.33**	**0.095**	**235.5**	**89.5**	**0.0**	**34.4**
2001	**4.43**	**0.086**	**155.2**	**85.3**	**0.0**	**42.1**
Overall Average	2.18	0.062	82.0	76.9		
Verified Period Average	**2.77**	**0.066**	**121.4**	**80.4**		

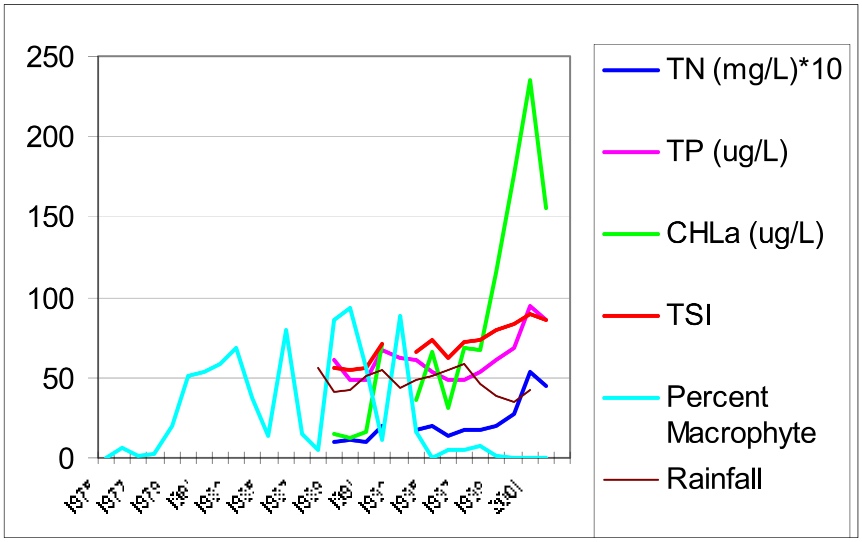
5.6 Macrophytes

Percent area covered by macrophytes (Table 13) was estimated based on data provided by Joe Hinkle (Biological Scientist DEP). This table contains the acreage of hydrilla and water hyacinth present on the lake during October of each year (1975 – 2002). Not shown is the acreage of each species controlled (herbicided) each year. To illustrate trends in macrophyte coverage, the percent of lake surface area covered by macrophytes was derived for each year by comparing the total area covered by macrophytes to the average lake surface area (Figure 13).

Table 13. Macrophyte Coverage in October (1975 – 2002).

Year	HYDRILLA Present In October (acres)	WATER HYACINTH Present in October (acres)	Total Acres Covered	Rainfall (Inches)	Average Lake Surface Area	Percent Macrophyte Coverage of Average Lake Surface Area
1975	2	350	352		5649	6.2
1976	30	10	40		5649	0.7
1977	150	5	155		5649	2.7
1978	1075	75	1150		5649	20.4
1979	2680	185	2865		5649	50.7
1980	2800	200	3000		5649	53.1
1981	3150	175	3325		5649	58.9
1982	3700	150	3850		5649	68.2
1983	1750	350	2100		5649	37.2
1984	413	380	793		5649	14.0
1985	4500	12	4512		5649	79.9
1986	810	10	820		5649	14.5
1987	293	4	297		5649	5.3
1988	4818	4	4822	55.8	5649	85.4
1989	5273	4	5277	40.5	5649	93.4
1990	3175	15	3190	42.3	5649	56.5
1991	575	65	640	51	5649	11.3
1992	5000	6	5006	54.3	5649	88.6
1993	850	40	890	43.7	5649	15.8
1994	5	1	6	48.9	5649	0.1
1995	265	25	290	51.2	5649	5.1
1996	250	8	258	54.7	5649	4.6
1997	400	0.5	401	58.2	5649	7.1
1998	40	1	41	45.6	5649	0.7
1999	2	0	2	38.3	5649	0.0
2000	0	0	0	34.4	5649	0.0
2001	0	0.3	0	42.1	5649	0.0
2002	0	0	0		5649	0.0

Figure 13. Annual Average TN, TP, Chl a, TSI, Percent Macrophyte Coverage, and Rainfall



From Figure 13, it can be seen that the percent coverage of macrophytes began oscillating about 1982, which is when large areas of the lake were beginning to be controlled for macrophytes. These oscillations continued until about 1994 when the macrophyte coverage was reduced to less than 6 percent and it has stayed low (near zero) since then without requiring any large applications of herbicide. Beginning in 1995, the concentrations of TN, TP, and Chl a began a dramatic increase.

Mr. Hinkle provided the following history of macrophytes in the Lake.

> "Until the introduction of hydrilla the lake had very few acres of submersed plants. Emergent vegetation at that time (pre-1974) consisted of shoreline fringe mainly composed of Panicum hemitomon, Paspalidium geminatum, and Nuphar luteum. On an average year, there would be from 80 to 150 acres of Nuphar (mostly on the south and northwest end of the lake) and 150 to 200 acres of other species of emergents dominated by the above listed grasses.
>
> Some major events in Lochloosa's aquatic habit include:
>
> 1993-94—Loss of about 100 acres of Nuphar as the result of non-target damage from hydrilla applications.
>
> 1994-1998—Floating islands problems and some management operation as a result of increased water levels.
>
> 1995-2002—Domination of algae community by exotic species of blue-green Cylindrospermopsis, which resulted in decreased water clarity and natural die-off of newly germinating hydrilla in both 1997 and 1998, with only a few hydrilla plants being observed until 2003. In 2003, improved water quality resulted in a few acres of hydrilla being present along the shoreline in shallow water. There was also a big decline in acres of water hyacinth present and controlled since 1995.

1997—Return of 60-70% of original Nuphar that was lost in 93-94.

1998-2003—Emergent vegetation including Nuphar has returned to pre-hydrilla levels (1974), probably as the result of low water.

2003—Color in Lake a result of tannins from increased water levels rather than algae. Water hyacinth and hydrilla have returned to a small extent to the lake."

It is well recognized that use of herbicides is a valuable tool to control exotic macrophytes in cases like Lochloosa where the exotic macrophytes dominated the lake, adversely impacting public use and the overall biological health of the lake. For Lochloosa, use of herbicides to control macrophytes in combination with the existing presence of the exotic blue-green algae Cylindrospermopsis may have played a significant role in the Lake switching from a macrophyte dominated lake to an algal dominated lake. The low Chl a concentrations (14-16 µg/L) during the period 1988 - 1990 resulted in low TSI values (54.8 – 56.4), but it would be a mistake to believe that because the Lake had a low TSI during this period that it was supporting a healthy well balanced population of fish and wildlife. The extensive coverage of exotic macrophytes was in itself an undesirable condition even though the TSIs were low. Use of herbicides in these cases to provide for the return of native emergent vegetation and the opportunity for the establishment of a well balanced population of phytoplankton is a valid and useful management option. With continued control of exotic macrophytes as necessary in conjunction with the reduction of nutrients after the implementation of the TMDL, it is speculated that domination of the lake by a single species of blue-green algae may also be controlled and a well-balanced population of phytoplankton and native emergent macrophytes can be achieved.

5.7 Model Parameter Adjustment

Using the measured concentrations of TP and TN, the lake's area and average depth, and the Event Mean Concentrations (see Table 4), the WMM and EUTROMOD models were adjusted to fit the measured data. To fit the measured data, all three kinds of EMCs for phosphorus (dissolved, sediment-attached, and total) were multiplied by 2.246, and all EMCs for nitrogen were multiplied by 0.5057 to obtain the best fit of the model predicted Lake concentrations to the estimates resulting from the regression equations. This adjustment to EMCs was used to improve the previously described poor performance of the Lake models ability to match the measured data.

It should be noted that changing the EMCs is not a calibration of WMM and EUTROMOD. The EMC parameters of both models were adjusted to recreate the measured nutrient concentrations resulting from the runoff of the nutrients from the Lochloosa Lake basin by the average annual rainfall into the lake. After adjustment of EMCs for annual average conditions, the external loadings estimated by the model were 32,563 lbs./year of TP and 55,444 lbs./year of TN.

5.8 Atmospheric Loading to Lake

Atmospheric loadings were estimated by utilizing the default TN and TP concentrations in the EUTROMOD model and the local rainfall. The loadings from precipitation directly onto the Lake (TP 5,906 lbs/year and TN 11,811 lbs/year) were subtracted from the total loadings, resulting in an estimate of the average production of TP and TN per one acre of land in all three subbasins. The uneven production of the nutrients was evident, with a much higher production of phosphorus and nitrogen in the Lochloosa Lake subbasin than in the two other subbasins (Figure 14). The higher rates may reflect the higher percentage of wetlands covering land near the Lake than in the northern portion of the watershed.

The total releases of nitrogen by the same three subbasins are shown in Figure 15. Again, the atmospheric loading was excluded from the comparisons. Similar to what was seen for phosphorus, the greatest source of nitrogen is from the Lochloosa Lake subbasin, even though the Lochloosa Creek subbasin is larger.

Figure 14. Annual Average Mass of TN and TP released from 'average' acre of land in each of the three subbasins of Lake Lochloosa

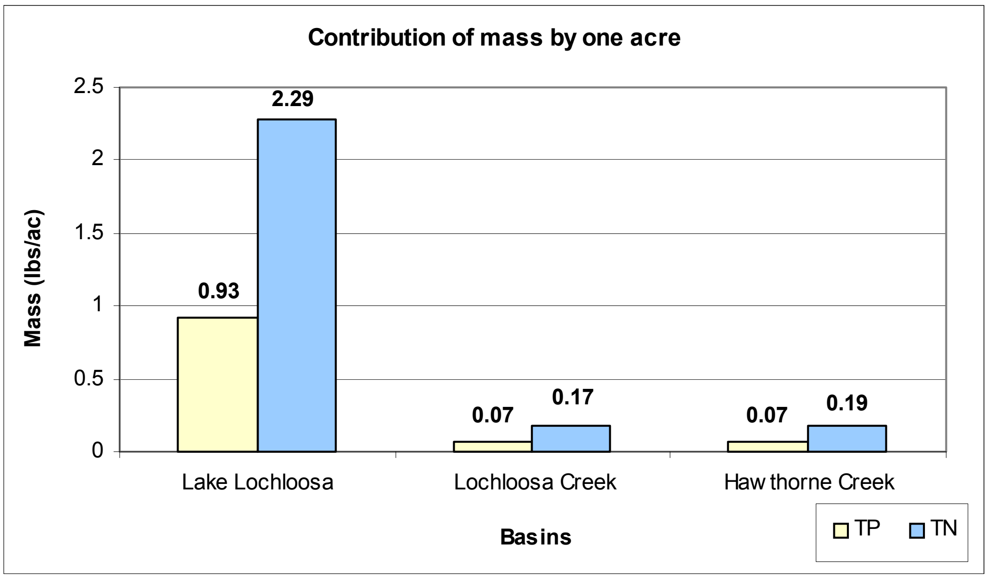
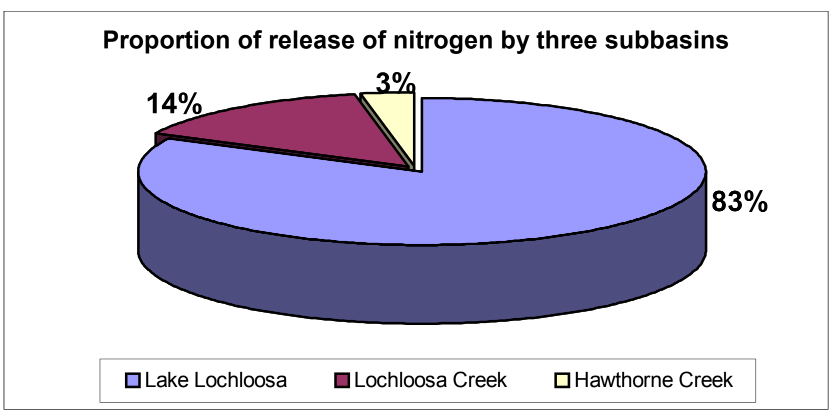


Figure 15. TN Relative contribution by sub basins



5.9 Natural background

As discussed previously, the average TSI for the verified period, 80.4, exceeds the threshold for impairment of 60. Examining the data for 1988- 1990, the TP averaged 0.052 mg/L and TN averaged 1.04 mg/L. The Chl a averaged only 14.4 µg/L. During this time, macrophyte coverage averaged 78 percent. It is believed that the macrophytes were limiting light into the lake and that this resulted in the low Chl a results. If the regression equation for the prediction of Chl a is used with the average nutrient concentrations above, the Chl a would have been 46.5 µg/L. These values would have resulted in a TSI of 63.9. Given the inability to accurately predict natural background conditions in the lake and the absence of paleolimnological data to determine natural background conditions, the IWR threshold for nutrient impairment for lakes (TSI of 60) was used to develop the final TMDL.

5.10 Determination of Assimilative Capacity of Lochloosa Lake

In order to determine the assimilative capacity, a series of WMM model runs were made with increasing levels of load reductions. For each model run, a TSI was calculated from the in-lake TN, TP resulting from the model, and the Chl a concentration predicted by the regression equation until a TSI of 60 was achieved.

Rather than simply reduce all loadings by a given percentage, the land uses resulting in anthopogenic loads in the basin were reduced. A given percentage of the human landuses were assessed as 'forest' and the septic tank loadings were reduced accordingly. The modeled loadings to the lake were converted to concentrations by use of EUTROMOD and the resulting Chl a concentrations calculated from the regression equation. TSIs were calculated for each set of results.

At a TSI of 60.5 (closest model run to TSI of 60), the in-lake, model predicted annual average TN and TP concentrations were 1.044 mg/L and 0.047 mg/L, respectively. The Chl a concentration predicted by the regression equation is 30.6 µg/L. Under current annual average conditions, the loadings predicted to the lake are 55,444 lbs/year and 32,563 lbs/year, for TN and TP, respectively. To maintain a TSI of 60, the maximum allowable annual average loadings to the Lake should be 34,613 lbs/year TN (38 percent reduction) and 12,896 lbs/year TP (60 percent reduction).

6.0 DETERMINATION OF TMDLs

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL has historically been expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

This equation has changed slightly in response to the evolution of the NPDES Stormwater Program, such that the WLA has been broken out into separate subcategories for wastewater discharges and stormwater discharges:

$$\text{TMDL} \cong \sum \text{WLAs}_{\text{wastewater}} + \sum \text{WLAs}_{\text{stormwater}} + \sum \text{LAs} + \text{MOS}$$

It should be noted that, in this modified equation, the various components of the TMDL may not sum up to the value of the TMDL because a) the WLA for stormwater is typically based on the percent reduction needed for **all** nonpoint sources and is accounted for within the LA, and b) TMDL components can be expressed in different terms [for example, the WLA for stormwater is typically expressed as a percent reduction and the WLA for wastewater is typically expressed as a mass per day].

WLAs for stormwater discharges are typically expressed as "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored and treated, they are not subject to the same types of effluent limitations as wastewater facilities and are instead required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of Best Management Practices.

This new approach is consistent with federal regulations [40 CFR § 130.2(I)], which state that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measure. The TMDL for Lochloosa Lake (Table 14) is expressed in terms of pounds per year and percent reduction.

Table 14. Lochloosa Lake TMDL Components.

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	Stormwater				
2738	TN	None	NA	34,613	Implicit	34,613	38
2738	TP	None	NA	12,896	Implicit	12,896	60

6.1 Load Allocations

The allowable LA is 12,896 lbs/year for TP and 34,613 lbs/year for TN. This corresponds to reductions from the existing loadings of 38 percent for TN and 60 percent for TP. It should be noted that the LA allocation includes loading from stormwater discharges regulated by the Department and the Water Management Districts that are not part of the National Pollutant Discharge Elimination System (NPDES) Stormwater Program (see Appendix A).

6.2 Wasteload Allocations

<u>NPDES Stormwater Discharges</u>

As noted in Sections 4 and 6.1, load from stormwater discharges permitted under the NPDES Stormwater Program are placed in the WLA, rather than the LA. This includes loads from municipal separate storm sewer systems (MS4). However, based on the information provided by EPA, no MS4 area was found overlapping the Lochloosa or Cross Creek watersheds and no stormwater loads were assigned to the WLA.

<u>NPDES Wastewater Discharges</u>

There is no $WLAs_{wastewater}$ for this TMDL because there are no facilities authorized to discharge wastewater to Lochloosa Lake.

6.3 Margin of Safety

An implicit margin of safety exists due to conservative assumptions used in the modeling process. Additionally, the estimates of septic tank failures were set to the maximum values instead of the mean values.

The Department recognizes that the absolute value of these loading numbers may be significantly different from the absolute loads calculated by other models, based on analysis using data from other sources, use of different assumptions, and/or differing interpretation of the results of other researchers.

6.4 Cross Creek

Because Cross Creek serves mainly as a conveyance system connecting Lochloosa Lake with Orange Lake, loadings to the Creek from Lochloosa Lake are the primary cause of the impairments to the Creek. The Creek is expected to attain water quality standards following implementation of the Lake TMDL because the Lake TMDL will require a 60 percent reduction in TP, a 38 percent reduction in TN, and a 72 percent reduction in Chl a. These reductions will significantly improve overall water quality in the Lake, including DO levels, with concomitant improvements in Creek water quality. For example, the proposed nutrient reductions for the Lake are predicted to decrease algal biomass from the current Chl a average in the Lake of 121 µg/L to approximately 30.6 µg/L. This will have a positive affect on reducing the diurnal fluctuations in DO and improve the DO levels of water leaving Lochloosa Lake through Cross Creek. Since Cross Creek is a short creek (1,600 meter) originating as the main outflow from the Lake, it is expected that similar reductions in nutrients and Chl a will occur in the Creek. These reductions in the algal biomass will reduce the DO fluctuations and the BOD that results from the breakdown of the algal cells.

7. NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

Following adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan for the Lochloosa Lake Basin. This document will be developed in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished.

The Basin Management Action Plan (B-MAP) will include:

- Allocations among the affected parties.
- A description of the load reduction activities to be undertaken.
- Timetables for project implementation and completion.
- Funding mechanisms that may be utilized.
- Any applicable signed agreements.
- Local ordinances defining actions to be taken or prohibited.
- Local water quality standards, permits, or load limitation agreements.
- Monitoring and follow-up measures.

It should be noted that TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated during the BMAP development process and subsequent Watershed Management cycles. The Department acknowledges the uncertainty associated with TMDL development and allocation, particularly in estimates of nonpoint source loads and allocations for NPDES stormwater discharges, and fully expects that it may be further refined or revised over time. If any changes in the estimate of the assimilative capacity AND/OR allocation between point and nonpoint sources are required, the rule adopting this TMDL will be revised, thereby providing a point of entry for interested parties.

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Appendix A

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as outlined in Chapter 403 Florida Statutes (F.S.), was established as a technology-based program that relies upon the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, Florida Administrative Code (F.A.C.).

The rule requires Water Management Districts (WMDs) to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a SWIM plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG has been developed for Lochloosa Lake at the time this study was conducted.

In 1987, the U.S. Congress established section 402(p) as part of the Federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES to designate certain stormwater discharges as “point sources” of pollution. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific Standard Industrial Classification (SIC) codes, construction sites disturbing five or more acres of land, and master drainage systems of local governments with a population above 100,000 [which are better known as “municipal separate storm sewer systems” (MS4s)]. However, because the master drainage systems of most local governments in Florida are interconnected, EPA has implemented the MS4 permitting program on a county-wide basis, which brings in all cities (incorporated areas), Chapter 298 urban water control districts, and the DOT (Department of Transportation) throughout the 15 counties meeting the population criteria.

An important difference between the EPA and the state stormwater permitting programs is that the EPA program covers existing discharges while the state program focuses on new discharges. Additionally, Phase 2 of the NPDES stormwater permitting program will expand the need for these permits to construction sites between one and five acres, and to local governments with as few as 10,000 people. These revised rules require that these additional activities obtain permits by 2003. While these urban stormwater discharges are now technically referred to as “point sources” for the purpose of regulation, they are still diffuse sources of pollution that can not be easily collected and treated by a central treatment facility similar to other point sources of pollution, such as domestic and industrial wastewater discharges. The DEP recently accepted delegation from EPA for the stormwater part of the NPDES program. It should be noted that most MS4 permits issued by EPA in Florida include a reopener clause that allows permit revisions to implement TMDLs once they are formally adopted by rule.